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(71) Applicant: **WATERTRAX INC.** [CA/CA]; 601 - 1311 Howe Street, Vancouver, British Columbia V6Z 2P3 (CA).

(72) Inventors: **GREEN, Ronald**; 202 - 1551 West 11th Avenue, Vancouver, British Columbia V6J 2B5 (CA). **WARN, Helen**; 8442 Nanaimo Street, Vancouver, British Columbia V5P 4N1 (CA).

(74) Agent: **SMITH, Paul**; Paul Smith Intellectual Property Law, Suite 330, 1508 West Broadway, Vancouver, British Columbia V6J 1W8 (CA).

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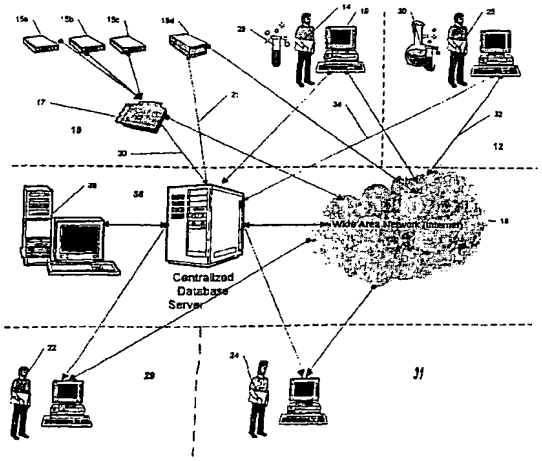

(57) Abstract: An integrated water quality monitoring system is provided for measuring, analyzing and maintaining the quality of water. Water quality measurements are obtained from a number of distributed sources, for example autonomous data acquisition instruments, laboratory analysis, user-entered results from on-site testing, and the data is communicated to a central database system through the Internet or other means. Remote users, which may includes users submitting water quality data and others can access the data stored in the central database system remotely and interactively. The system may provide text-based and graphical output and analysis. It may also provide to users input parameters regarding data acquisition, and access to functions such as receiving notification when a measured water quality characteristic exceeds an applicable guideline, indicating where user data entry appears erroneous, and providing advice and instructions for maintaining water quality.

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TITLE OF THE INVENTION

INTEGRATED WATER QUALITY MONITORING SYSTEM

FIELD OF THE INVENTION

The invention herein disclosed relates to a system for water quality monitoring. Specifically, the invention relates to a system for measuring, analyzing and disseminating data regarding the quality of water through a centralized database.

BACKGROUND OF THE INVENTION

Maintenance of quality water systems is of primary importance to the continued survival of the human race. Operators of water systems often keep records of water quality characteristics to ensure that their systems meet standards for water quality. The U.S. Environmental Protection Agency has recently introduced draft legislation for public drinking water systems in the U.S., presenting significant challenges to water systems managers.

Many types of water systems require monitoring and testing, including drinking water systems; wastewater facilities; natural water bodies such as streams, rivers, lakes, oceans; storm water collection systems; field irrigation systems; greenhouse irrigation systems; groundwater monitoring systems and public swimming beaches and pools. Types of data that require monitoring include: physical and chemical water quality parameters, radiological water quality, microbiological water quality parameters (e.g. protozoic and bacteriological testing) and facility operations data (e.g. flow rates, volumes, water levels, pressure and temperature).

In the field of environmental monitoring, it is known to provide a plurality of distributed environmental sensors for water quality, which are located at various physical locations in the environment of interest and are coupled to a database. U.S. Patent No. 5,063,505 discloses a computer aided management system for public utility wastewater collection systems. U.S. Patent No. 5,553,492 discloses a system for measuring real time groundwater data and providing graphical data for a user located at a database. U.S. Patent No. 5,905,570 discloses a water monitoring system with reflectance radiometer sensors that upload data to a database that provides users with irradiance measurements and chlorophyll concentration data. The aforementioned patents all describe environmental monitoring systems having distributed sensors in a particular environment of interest, the sensors being in communication with a database.

U.S. Patent No. 5,892,690 describes an environmental monitoring system including environmental sensors in communication with a database for storing environmental data from many sites. An Internet connection between users and the database permits users to access data contained in the database.

It is also known to provide distributed sensors, a database, remote user access to the database via the Internet, and a limited form of interactive user interface. U.S. Patent No. 6,023,223 ("the '223 patent") discloses an early warning detection system, including remotely located environmental sensors having a wireless communications link (i.e. satellite) to a database server. An interface is provided between the database server and the Internet, whereby a user can remotely access the environmental data contained in the database server. A user may also input measurement parameters and diagnostic commands from a remote location. These user-entered parameters and commands may contain trigger levels for certain

measurements, such that when measured data exceeds a trigger level, the system can issue an alarm or warning to the user.

Although the '223 patent discloses a limited form of interactive user interface (i.e. having user-entered trigger levels along with corresponding alarms and warnings), the invention is limited, because it only discloses autonomous sensors located in the environment of interest. This limitation is significant, because many environmental characteristics of interest are not easily measured by autonomous sensors and may require human interactive testing in a laboratory or in the field. For example, in a water monitoring system, measurements for certain pesticides, fecal bacteria and other characteristics of interest are typically done by sampling water in the environment of interest and then taking the sample back to a lab for further analysis. Other parameters, such as chlorine, pH and color may be best measured by a human operator performing on-site analysis in the field. In addition, an on-site operator is able to test the veracity of the measurements made by autonomous sensors.

The above discussion indicates that the state of the prior art in environmental monitoring systems is limited and does not offer a comprehensive system with a full level of interactivity, and the effective dissemination at large of useful information derived from a variety of different types of data sources, and from a variety of different locations. Accordingly, it is an object of the present invention to provide such a system.

It is a further object of this invention to provide such system tailored to water quality and in which a remote user's query of the database may be interactive, and which is capable of providing useful feedback to the remote users or the on-site facilities and operators to improve their control of the water quality.

It is yet a further object of the present invention to allow the user to input data retrieval and measurement parameters, to analyze data in a sophisticated manner, and to receive graphical and textual analysis of measured data, as well as advice and warnings about measured data.

It is a further object of the invention to provide a means for users to determine the appropriate government regulations and guidelines that apply to the tested environment and to compare data presented by the user with such guidelines.

It is also an object of the present invention to permit users located either on-site or in laboratories to supply measured data and information to the centralized database from a remote location.

It is a further object of the invention to facilitate the automatic electronic transfer of water quality data results from laboratories to the centralized database.

It is also an object of the invention to provide advice for managing water systems by combining a knowledge base on water management practices with user data to advise the operators of facilities on best practices, and save them time and money by using their historical data to assist their decisions. This may include such services as maintenance scheduling, knowledge-based recommendations and advice on sampling of water for analyses.

It is yet a further object of the present invention to provide a water quality monitoring system with a centralized database having several data input methods, including autonomous sensors and data acquisition units located in the environment of interest, user input from on-site facilities and laboratories and automatic electronic transfer of test results from laboratories.

Other objects of the invention will be appreciated by reference to the description of the preferred embodiment of the invention.

SUMMARY OF THE INVENTION

According to one aspect of the invention, there is provided a water quality monitoring system, comprising a centralized database system for collecting and storing water quality data. The database system includes at least one database and application software which includes means for analyzing water quality data. The database system receives water quality input data from a plurality of remote input sources. A user interface is provided for presenting water quality data to remote users through a distributed wide area network.

In another aspect, the input sources include a plurality of different types of sources of data, including autonomous water quality data collection instruments installed in a sampling location, persons submitting water quality measurement data from on-site water samples, water facility operators, and water quality test laboratories remote from a water sampling location.

In another aspect the database system maintains historical water quality data and provides comparisons of incoming water quality data with the historical information. The historical information may also be used to provide reports and recommendations regarding water management practices, or monitoring requirements.

In another aspect, the database system maintains information regarding the various water quality parameter guidelines issued by various authorities, and compares incoming water quality data to the applicable guideline. One aspect of the invention

involves the method of determining the applicable guideline for a given water sampling location.

In another aspect, the database system is used by both remote users inputting data, and by users simply wishing to view data collected by others.

In yet another aspect, the database system maintains information regarding each user and the data submitted by each user. This information may include information for tailoring a web interface for the use of particular users.

In another aspect, the database system displays to remote users both current guidelines and/or monitoring requirements, and proposed or anticipated future guidelines and/or monitoring requirements. The invention may also provide summary and background information regarding particular water quality parameters.

In another aspect the invention provides the capacity to share water quality data among several remote users. Users may specify the level of accessibility of their data to others.

In another aspect, the invention provides for the use of bar codes associated with water sampling sites and the database system uses bar code information to facilitate the data collection task of remote users.

Other aspects of the invention will be appreciated by reference to the detailed description of the preferred embodiment and to the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the invention will be described by reference to the drawings thereof in which:

Fig. 1 is a comprehensive schematic diagram of the environmental monitoring system in accordance with the present invention;

Fig. 2 is a diagram of the centralized database server and the corresponding server application software; and,

Fig. 3 is a schematic diagram of the system hardware and software architecture, showing how users query the database server and enter data to the database server from remote locations.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

In the preferred embodiment, illustrated generally in Fig. 1, the environmental monitoring system is used to measure water quality in a particular environment of concern 10, for example a public drinking water system. It should be understood, however, that the invention is applicable to many types of water systems including, but not limited to, drinking water systems; wastewater facilities; natural water bodies such as streams, rivers, lakes, oceans; storm water collection systems; field irrigation systems; greenhouse irrigation systems; groundwater monitoring systems and public swimming beaches and pools.

Water quality data may be and typically is collected through a variety of means. Certain data is available relatively quickly and autonomously from permanently installed autonomous data acquisition instruments (illustrated as 15a-15d in Fig. 1). Dataloggers and computers 17 may be used to collect and store the data from one or more such devices for periodic transmission to a remote location. Other water quality data requires more involved testing at laboratories 12 by laboratory personnel 25. In yet other cases, water facility operators 14 collect data. The present invention provides a means for collecting and analyzing measurement data from such disparate types of data sources through a centralized database system 16 receiving information from the sources through a wide area network such as the Internet 18 or through other means such as direct connections 20. Use of a wide area network such as the Internet facilitates the use of a variety of data input techniques and the collection of data from different types of remote sources and its consolidation and dissemination through the database system 16.

The centralized database system 16 includes databases (described in more detail below) as well as application software, including server software for accessing the databases, and an analysis component for analyzing incoming water quality data and relating it to information in the database. For convenience this description and the drawings will proceed using the term "database server", that term being understood to include the overall centralized database system unless otherwise noted.

Water quality specifications may consist of non-compulsory guidelines issued by advisory or supervisory bodies, or of compulsory standards enacted into legislation, by-laws or by decree. The following disclosure will proceed using the single term "guideline" to include both non-compulsory guidelines and compulsory standards, unless otherwise noted.

The system 16 offers sophisticated data analysis and a variety of output formats. The server is also provided with a user interface to accept user queries from remote users 22, 24 (as well as from on-site facility operators 14 and laboratories 12) enabling them to extract water quality measurement data.

Regulations and recommendations related to water quality usually include monitoring requirements that have criteria such as frequency of sampling and characteristics of the analytical method to be used for each parameter. These monitoring requirements will be included in the server database for many jurisdictions. Users will also enter information about their specific water system, such as population served and type(s) of water source(s). The database server 16 will then provide to users useful information regarding monitoring requirements for their particular circumstances. Users can also determine whether they meet the monitoring requirements for specific parameters, based on the regulations or recommendations for their jurisdiction and their past sampling data that are contained in the database server.

Referring to Fig. 3, server 16 further includes a database 26 of water quality guidelines against which to compare the measurement data and means to determine the particular guideline applicable in a given case, as described in more detail below. This solves a longstanding problem that users have heretofore been faced with in attempting to sort through a multiplicity of guidelines from different levels of jurisdictions and for different parameters for the particular type of water system of interest, and for the particular parameter of interest.

Referring again to Fig. 1, a plurality of autonomous data acquisition instruments, i.e. measuring devices 15a, 15b, 15c and 15d are deployed in the environment 10 to be monitored. Autonomous data acquisition instruments 15a, 15b, 15c, and 15d

comprise sensors and electronics. Measurement data may be transmitted to the central database server 16 in substantially real time. Alternatively, data acquisition instruments 15a, 15b and 15c may be connected to a data acquisition unit 17 (typically a datalogger or a computer) that may process the incoming data, and store data for a period of time for subsequent (usually periodic) transmission to the central database server 16. Typical data suited to autonomous data acquisition includes turbidity, concentrations of certain chemical compounds (such as fluorides), temperature, pressure, water level and flow. Data acquisition instrument 15d and the data acquisition unit 17 are in communication, via the Internet 18 with the central database server 16.

In some cases, the data acquisition unit 17 and data acquisition instrument 15d may bypass the Internet 18 and be directly connected to the centralized database server 16, by dedicated connections 20 and 21 respectively. In another embodiment (not shown) that may be used in conjunction or in the alternative, data acquisition units and data acquisition instruments may be linked to the wide area network 18 or the centralized database server 16 via a wireless communication means.

Figure 1 depicts an "on-site operator" 14 located in the environment to be monitored 10. The on-site operator 14 takes samples 28 of the water for the purposes of making additional measurements regarding water quality and also records periodic readings from the data acquisition instruments. Typically, these measurements would be types of data that may not easily be monitored by the data acquisition instruments 15, for example color, certain chemical tests, bacteriological indicator tests and visual observations. Some of the on-site records are also used to verify the data received from the data acquisition instruments and data acquisition units.

As with the data acquisition unit 17 and data acquisition instrument 15d, the on-site operator 14 can communicate with the centralized database server 16 in a variety of different ways. Figure 1 depicts a connection 18 between the computer 19 used by the on-site operator 14 through the Internet 18 and to the centralized database server 16. It should be noted that Figure 1 depicts the on-site operator 14 using a computer 19, but the computer 19 may be replaced by other more efficient (or lower cost) devices used to receive input data and upload it to the Internet 18. Such devices include hand held computers such as Palm Connected organizers and Internet appliances, whether line based or wireless, possibly using voice recognition software for data input.

In accordance with the present invention, an additional source of measured data includes data obtained from analysis in a laboratory 12. For some types of data involving extended testing or testing on equipment that is not mobile, samples 30 are taken from the environment to be monitored 10 and physically transported to the lab 12, where they can be more thoroughly analyzed. Types of data that are measured in this manner include, without limitation: fecal bacteria concentrations, concentrations of pesticides, concentration of various chemicals, other bacteria or protozoic organisms and radiological quality data.

As with the other sources of data, data acquired in the lab 12 is uploaded via connection 32 to the centralized database server 16 through network 18. Alternatively (or in conjunction), the lab data is uploaded directly to the centralized database server 16 by connection 34. However, compared to data submitted by on on-site personnel and by autonomous data acquisition instruments, comprehensive lab test results are typically more detailed and multi-faceted. They may also be entered into a database associated with the lab prior to dispatch to the database server. Accordingly, the preferred means of transmitting the data is not through user

entry into a browser but rather by data exchange between the lab's computer or database, and the database server 16. The database server 16 is therefore configured to accept such data exchange from labs.

The centralized database server 16 is situated at a location 36 that is distinct from the environment to be measured 10. When the data from a variety of sources reaches the centralized database server 16, it will be stored in a structured query language ("SQL") database 38. In one embodiment (not shown), the centralized server 16 is comprised of a network of server computers, each with its own CPU and data storage resources.

In accordance with the present invention, users 14, 25, 22 and 24 may access the centralized database server 16 from any location with a connection to the Internet 18. For example, user 22 is situated in location 29, which may be the downtown office of a regional planner. User 24 is situated in location 31, which may be a construction site, where water information is required. An advantage of the present invention is that the users who are uploading data, such as the on-site operator 14 (situated in the environment to be monitored 10) and the lab technician 25 (situated in laboratory 12) may simultaneously have access to the data stored on the centralized database server 16. The remainder of this disclosure describes users with reference to user 22, but it should be understood that additional users 24, on-site operators 14 and lab technicians 25 all have access to the same resources as users 22 and 24.

Referring now to Figure 2 in conjunction with Figure 1, the centralized database server 16 is depicted in greater detail. The centralized database server 16 is accessed by server application software 40, which is operative to control an interactive user interface (not shown).

Through server application software 40, users 22 will have graphical and textual access to measurement and analysis data 41 contained on the centralized database server 16. The server application software 40 will allow users 22 to view the data in a variety of meaningful ways, such as graphical output as a function of time, comparison graphs against governmental and regulatory standards (both current and proposed), and statistical analysis of data and test results. Users will also be able to selectively download this data in a variety of standard formats.

There are many established water testing laboratories that have internal data management systems using individual computers or computers connected through a local area network to a database server. Typically, the laboratories with such data management systems print reports of the results from analyses of water samples, using the internal database as the source of the results, and then mail or fax the report to the customer that sent the sample to the laboratory.

The invention will provide an efficient and effective means for automatic electronic transfer of data files, that contain the results of analyses of water samples, from the laboratory 12 data management systems to the centralized database server 16. Then, using data exchange types of software programs, the data files from the laboratory 12 will be converted into a format compatible with the SQL database located on the centralized database server 16. Unique data exchange software programs for many laboratories located all over the world will be stored on the centralized database server 16. Information specific to each of the laboratories, such as available tests, detection limits, analytical methods and geographic location will also be stored on the centralized database server 16.

The names of laboratories that have arranged to provide electronic transfer of data files, or to input the data directly into the centralized database server 16 using web

browser based data entry, will be shown on the user's screen with a hypertext link. When a user clicks on a hypertext link for a lab they will be presented with a sign-up form for obtaining automatic electronic transfer of data from that lab.

When the lab receives the request for electronic data transfer, they will add that information to their database for the customer (for existing customers) and will create a new database record for new customers. The customers will have the choice of continuing to receive mailed or faxed test results in addition to electronic data transfer. All future test results for such customers would then be automatically transferred electronically to the centralized database server 16 and stored in the user's data storage area for the relevant sampling site.

In a further aspect of the invention, the data from the laboratory 12 data management system will be transferred to a special staging area of the centralized database server 16. Access to the staging area would be restricted to certain users such as Environmental Health Officers (EHO) that would review the data and add comments (for example, interpretation of the results) to a comment field. Upon completion of this activity by the EHO, the data would be sent to the user's data storage area for the relevant sampling site.

A significant aspect of the invention is the collection and use of current and proposed water quality guidelines and standards. The centralized database server 16 contains comprehensive information about guidelines and standards for water quality set by various territorial jurisdictions around the world and by various authorities having different competencies within each jurisdiction. For example, in Canada, Health Canada publishes a document entitled "Guidelines for Canadian Drinking Water Quality" which contains non-compulsory standards for drinking water quality. Provinces may mandate their own legislated standards, and cities may

pass by-laws or public health officers may issue directives establishing water quality standards. At each level of jurisdiction, there may be different guidelines or standards for drinking water, wastewater, etc. In the U.S., the United States Environmental Protection Agency (USEPA) prepares minimum legislated standards for drinking water quality that apply nationwide, but each state may elect to set more stringent standards.

The centralized database 16 includes details of guidelines for the various levels of jurisdiction worldwide, including a breakdown of guidelines for each specific water quality parameter that may be of interest (for example, arsenic concentration). Thus for a given city, the database will contain the guidelines for that city for drinking water, waste water, pools, beaches, etc. These will be maintained as a group of records associated with the city, each record providing the applicable guideline for a specific water quality parameter.

In many cases, a lower level jurisdiction elects not to establish guidelines itself, but defers to the guidelines established by a higher level of jurisdiction. For example, a city in Idaho is required to comply with state legislation regarding drinking water quality for chemical parameters such as arsenic or total trihalomethanes. However, the State of Idaho simply uses the USEPA standards for these chemical parameters, and does not publish its own list of standards. A city in California will be subject to the legislated standards of California in relation to arsenic or trihalomethanes, which may be more stringent than the standards required by the USEPA.

The centralized database server 16 determines which guidelines apply to a given water use or water source site for a specific water quality parameter by first consulting the database record for that parameter for that city. If the city has established its own guideline for that parameter, it will appear in the record. If the

city has not established its own guideline for that parameter, the record will provide an identifier pointing to a "parent" guideline to which the city defers.

Similarly a higher level of jurisdiction will have its own records for each parameter. If that level of jurisdiction has not established its own guideline for the parameter in question, the record for that parameter will point to the next higher level of jurisdiction, and so on. The State of Washington could have as its parent for that parameter the applicable guideline issued by the US Environmental Protection Agency (USEPA).

Typically the hierarchy of jurisdictional levels will be: city, health region, state/province, country.

The system of the present invention is flexible in that a number of levels may be included in the jurisdiction hierarchy. For example, the highest level of the hierarchy need not necessarily be the country. Any agency, such as the World Health Organization, might issue a guideline that might be assigned a level within the hierarchy. Such guidelines can then be used as the parent for any jurisdiction in the level next below it in the hierarchy.

Some jurisdictions may issue partial guidelines. For example, in the case of Drinking Water Chemical Parameter Guidelines, many Canadian Provinces use the Health Canada (HC) Guidelines; others use the HC Guidelines for most parameters, but specify their own Guideline values for specific parameters. The centralized server database as described above is able to correlate the specific parameter which is the subject of an enquiry to the appropriate guideline applicable to that parameter in the given locale of concern so as to respond to the enquiry with the correct guideline.

In addition to providing responses to users simply enquiring as to certain guidelines, the server application software 40 provides the capacity to compare the water quality data input by a user with the guidelines applicable for the parameters of interest and for the applicable jurisdiction. Similarly the server application software 40 is able to compare the frequency of water sampling and analyses being conducted by a user and determine whether it meets the monitoring requirements of the parameter of interest and for the applicable jurisdiction.

In the preferred embodiment, the server application software 40 compares the measured data 41 to the standards required for a particular user 22 having regard to the applicable jurisdiction, provides users 22 with warnings when the standards are about to be exceeded and provides users 22 with alarms when the standards are exceeded. These alarms and warnings could have a variety of forms, such as e-mails, faxes, pages or on-screen alarms. Notifications can also be provided to users 22 for changes in governmental and regulatory guidelines for water quality, when new data from a lab has been added to their data, when a lab receives a water sample sent by the user and when a lab is overdue in providing test results.

The server application software 40 may also analyze current (41) and historical measured data 42 for a particular measured environment, irrespective of or compared to current or proposed guidelines, and provide water facility operators and owners with information, knowledge, technical data or suggestions on steps to be taken in the facility or regarding more up-to-date water management practices to be considered.

In addition to providing users 22 with access to measured data and information about that data, the server application software 40 may provide users 22 with a variety of input-related functions. On-site operators 14 and lab technicians 25 may

enter data directly onto a preformatted data input interface. The server application software 40 may also provide additional functions, such as validation of user-entered data. A user may also be provided with an opportunity to change the measurement parameters of the data collection instruments 15 and data acquisition unit 17. Measurement parameters that may be changed in this manner include, without limitation: the frequency of sampling and recording and the actual parameters recorded.

For large water distribution networks, the server application software 40 provides advanced analysis of the distribution networks, including comparative analysis of different geographic regions within the network and tracking of flows and pressures that result from specific conditions. For example, the use of high flows in fire hydrants may have adverse effects on other areas of the distribution network, and, as such, need to be closely monitored.

Obviously, the managers of water systems may consider the information on their environmental monitoring system to be of a confidential nature. Consequently, each user 22 will be assigned a login identity and password to access data regarding their water system. In contrast, some data for particular water systems, such as public beaches, may be in the public domain. In this case, the server application software 40 will provide various levels of security. For example, some information related to the water quality of public beaches may be made generally accessible to the public, but a user will require a log-in identity and password should they want to input data or access specific information, that may not be considered public domain. Facility owners and operators may choose to allow other facility operators to access all or some of their specific measurement data and various levels of access may be definable by the provider of the input data.

A facility may be established in the server 16 to allow the sharing of data. Accordingly, anyone who elects to share their data will be able to share the data of all others who are willing to share similar data. Thus, the users of the invention will be able to share data collaboratively, for example for large-scale analysis of water-quality data. Such capability would be very difficult to provide without the present invention. For example, Environmental Health Officers will be able to compare water quality data with epidemiological data regarding disease outbreaks for specified geographic areas.

Sharing is also associated with the data for a sampling site. When creating a sampling site, a user determines who has access to the data for that specific sampling site. The user can decide to share with everybody, nobody, certain regulatory agencies or only with specific people. In order to share only with specific people, the user uses the web browser to enter a unique identification code (that is stored in the centralized server database) for each specific person. Authorized users would have various methods for accessing "shared" data. One method would be to search for all available data for a specified watershed (for surface water sources). Another method would be to search for all available data for a specified geographic area; this would be especially useful for groundwater sources of water. Much of the data entered by users would likely be designated as being in the public domain or as being available at least to regulatory or government organizations, for example for mandatory reporting purposes, such reporting being effected through the system of the invention. For example, in British Columbia the "Safe Drinking Water Regulation." the "Forest Practices Code of BC Act" (and related regulations) and the "Waste Management Act Municipal Sewage Regulation" all require organizations to provide water quality data to various departments of the Government of British Columbia. At the present time the data is stored in separate

databases and is difficult to share amongst many people. The present invention will allow many more people to use the available data.

Figure 3 depicts the system architecture. A user 22 uses a computer (or Internet access appliance) 44 to access the login page (not shown) of the centralized database server 16. After successfully entering a login name and password, the user 22 may make a request for information from the system. The user will enter commands to the system through a browser 46. The web server application software 40 receives these commands. Depending on the services that the user 22 has requested, his command may be handled by one of the standard active server pages (the "standard ASPs") 48. If the user 22 requires sophisticated data retrieval or desires more functionality than is available on the standard ASPs 48, then the command may be routed through a user-specific ASP 50. As the name suggests, each user 22 may define a profile for a user-specific ASPs 50, which is particularly suited to that user's needs. The web server application software 40 will allow users flexibility in formatting personal interface pages. The data required to render these pages will be stored on the server 16 in a user database 52. For example, each user may build a portfolio of water quality parameters that are of particular interest to that user and the user may specify those jurisdictions that are of interest to that user. This enables each user to have a customized view of the database of comprehensive information about guidelines and standards for drinking water quality (e.g. a user's default screen may provide information for that user's particular jurisdiction).

The functional units of the web server application software 40 (i.e. the standard ASPs 48 and the user-specific ASPs 50) are in communication with the database server 16, either directly using stored procedures 54 in the database or indirectly using program libraries of functions. Figure 3 shows that the user 22 has sent a request that is being handled by the standard ASP 48 portion of the web server

application software 40. The standard ASP 48 communicates the data request to the database server 16. In general, the database server 16 is comprised of three types of data: a user database 52, a guidelines database 26, and a knowledge base with stored procedures 56. The database server 16 is supplemented by program libraries which can be used for data validation, resolving security issues, etc. and may provide a data access layer between the user interface and the raw database information. The user database 52 contains raw user data and the data necessary to generate user-defined ASP profiles 50.

The guidelines database 26 contains records and data for each level of jurisdiction for each parameter, associations between the various levels of jurisdictions within a hierarchy, and background information regarding the guideline.

The knowledge base with stored procedures 56 contains specific knowledge regarding water quality management. Depending on the user 22 request or on the state of the water quality measurements in the user database 52 and the specific parameters of the user's facility (e.g. population served), the specific knowledge and stored procedures 56 may provide the user 22 with recommendations about managing their particular water facility.

The database server 16, possibly in conjunction with the program libraries, validates and handles the request from the standard ASP 48, retrieves the required data and communicates the data in required format back to the web server application software 40 in the form of an HTML page, sending it back to the user's Internet browser 46 where the data is displayed for the user 22 in the requested format.

After logging on, a user 22 can also enter data manually. Such users 22 may be conducting water quality tests on-site or in a laboratory as discussed previously. The user 22 (through their browser 46) sends a request to the web server application

software 40 indicating that data entry is forthcoming. The web server (usually, but not necessarily, through a user-specific ASP 50) responds, sending an HTML data entry page back to the user's browser 46. The user 22 then enters the data, which is submitted on the HTML page to the web server application software 40. The web server application software 40 validates the data (usually using its stored procedures and/or executable programs and scripts 54) and converts the data into the form required for storage in the user data section 52 of the database server 16. In this manner, the user 22 may enter data manually into the database server 16 from remote locations such as the laboratory or in the field.

Users will be able to view data from the various sources in a variety of formats for the chosen water quality parameters in a variety of ways. The actual results reported by the user for the chosen water quality parameters may be compared with the guidelines and standards for the selected jurisdictions and the comparison may be displayed in the form of a table, graph or chart. Choices for various periods of time for the charts will be provided, such as 1 day, 5 days, 1 month, 3 months, and 1 year. An additional feature of the present invention lies in the type of information presented on a web page in response to an enquiry involving guidelines. Such an enquiry may be of a purely informational nature regarding an applicable guideline, or it may be in connection with displaying a comparison between a measurement value and the corresponding guideline.

According to the preferred embodiment, the page in question includes:

1. The guideline itself (i.e. the maximum or minimum parameter value).

2. A statement of the rationale for the guideline.

3. A summary description of the element, compound, or physical or chemical effect in question.

4. A description of the health implications.

5. A statement of any anticipated, targeted or proposed guidelines.

6. A statement of current monitoring requirements.

7. A statement of future monitoring requirements.

It will be appreciated that the page need not necessarily include all of the foregoing information. Nonetheless, providing information such as that described above in the same location will be very useful to any users interested in the guidelines.

Access to anticipated or proposed guidelines will be of particular use to those facility operators who need to predict future compliance with guidelines, for example to plan capital improvements and the like to their facilities.

The foregoing information may be embodied in a page displayed for a particular parameter, for example concentration of arsenic in drinking water. It may be provided in response to an informational request as to an applicable guideline, or it may be provided in conjunction with the display on the same page of the measured value of the same parameter supplied by the user (either in that session or supplied in a previous session by one of the system inputs).

In a further aspect of the invention, bar code readers are used with wireless devices to provide added functionality. Bar code labels will be placed on water sampling

sites (e.g. taps), water quality-testing instruments, measuring devices and facility equipment. Wireless (or other input) devices equipped with bar code readers will then be able to access the data contained in the bar code to improve the process for manual data entry. When the bar code reader scans the bar code label, a site-specific data entry form will be displayed on the screen of the wireless device. Data about the user's name, the item (e.g. meter, instrument, tap), the date, and time will automatically be recorded with the sample, obviating deficiencies and lapses common in manual testing and data entry. The user would then enter the remaining required data into the data entry form that is displayed on the screen of the input device. This will ensure that all required data are accurately entered and supplied.

The use of bar code readers and voice recognition technology also provides an opportunity to improve quality assurance when used for water sampling procedures. The operator would first scan the bar code at the sample site with the bar code reader/input device. The user would then be presented with a data entry form on the screen of the input device. Data about the user's name, the sampling site, the date, and time will automatically be recorded in the master database and shown on his screen. The user would then enter data about the type of analyses desired; i.e. identify the specific water quality parameters to be analyzed. An option for identifying the type of analyses would be to scan a bar code that is one of many on a page that lists bar codes by type of analyses. Another option would be to use voice recognition technology for the data input. The lab would be sent a report of the water-sampling event. The lab would then assign a sample identification code to the sample. This will improve quality assurance of sample tracking when it arrives at the lab, decrease the amount of labour needed at the lab for entering sample information upon receipt of samples, and also assist the lab with planning of their workload. An option to further automate the water sampling procedure will be available. The user will be able to print labels for the water sample containers that

contain sample information. The printed label would include a bar code that identifies the sample location. This will allow a data quality control check at the time of sampling. The server will send an alarm to the user via the wireless device if the sample location on the label bar code does not match the sample location on the bar code located on the sample tap.

The use of a bar code arrangement in association with the database of the invention also provides relatively easy access to site-specific maps and drawings. For example, if a bar code that is located on a fire hydrant is scanned using a wireless device, then an option on the menu will be to look at an as-built drawing of above and below ground utilities in the vicinity.

It will be appreciated that the invention allows water facility managers to more effectively manage the operations, and provides the tools enabling them to do so. In addition, it serves to consolidate water quality data from a variety of sources, and provides the added feature of correlating the data to established guidelines, including the ability to identify the particular guideline and apply a comparison. This in turn enables a level of feedback and interactivity, as well as information dissemination, that has heretofore been unavailable in the field of water quality management.

The characterization of groundwater aquifers will be improved by analyzing on a larger geographic scale the water quality data contained in the master database for groundwater sources, allowing hydrogeologists and well drillers to determine the best location for drilling water wells. This will assist with the identification of groundwater contamination on a large scale.

Surface water data such as raw water quality data and water level and flow rate data from several different sites can be projected upon a map of surface water sources, so that others considering the use of the same water source are able to make more informed decisions. For example, this will be very useful preparing watershed assessments for community watersheds, which is a requirement of legislation related to forest management in some jurisdictions.

Because the technology integrates the data in a comprehensive database, including historical data, new analyses will be available to users.

It should be understood that the above description is intended for illustrative purposes only, and is not intended to limit the scope of the present invention in any way. Those skilled in the art will appreciate that various modifications can be made to the embodiments discussed above without departing from the spirit of the present invention.

CLAIMS

1. A water quality monitoring system, comprising:

a centralized database system for collecting and storing water quality data, including at least one database, and application software including analysis means for analyzing said water quality data;

a plurality of remote input sources communicating water quality data to said centralized database system;

a user interface associated with said database system for presenting water quality data to remote users through a distributed wide area network.

2. A monitoring system as in claim 1 wherein said plurality of input sources comprise at least two of the following: autonomous water quality data collection instruments installed in a sampling location, persons submitting water quality measurement data from on-site water samples, water facility operators, and water quality test laboratories remote from a water sampling location.

3. A monitoring system as in claim 2 wherein said autonomous collection instruments communicate water quality data to said database system substantially in real time as water quality data is collected.

4. A monitoring system as in claim 1 wherein said database system stores historical water quality data according to sampling locations.

5. A monitoring system as in claim 4 wherein said database system, upon receiving new data for a given sampling location from an input source, compares the new data to historical data from said given sampling location.

6. A monitoring system as in claim 5 wherein said comparison is reported to said remote user.

7. A monitoring system as in claim 4 wherein said historical data is used to determine whether the monitoring requirements for a given water quality parameter and for a given sampling location have been met.

8. A monitoring system as in claim 7 wherein said determination is further made having regard to the particular jurisdiction in which the sampling location is located.

9. A monitoring system as in claim 8 wherein an input source is one of said remote users and a recommendation is provided to said remote user in relation to the water management practices at said sampling location.

10. A monitoring system as in claim 1 wherein said database system includes a guidelines database of prescribed or recommended guidelines for a plurality of water quality parameters.

11. A monitoring system as in claim 10 wherein said guidelines database includes information relating to a hierarchy of jurisdictions that potentially cover a given water sampling location and information identifying the parameters applicable for each jurisdiction.

12. A monitoring system as in claim 11 wherein said database system automatically determines the applicable guidelines for a given water quality parameter for a given water sampling location corresponding to incoming water quality data, having regard to the competent jurisdiction over that location and the nature of the parameter of interest.

13. A monitoring system as in claim 12 wherein said database system compares the applicable guidelines to the incoming water quality data and provides a report of the results of said comparison.

14. A monitoring system as in claim 11 wherein said guidelines database includes a breakdown of guidelines for a plurality of water quality parameters for each jurisdiction.

15. A monitoring system as in claim 12 wherein said guidelines database includes a plurality of database records, each record containing the guidelines for one water quality parameter for a given jurisdiction, and said determination is made by:

consulting the database record for said given water quality parameter for the lowest level of jurisdiction in said hierarchy;

determining whether said record includes a guideline set by said lowest level of jurisdiction;

if a guideline appears in said record, characterizing said guideline as the applicable guideline;

if no guideline appears in said record, determining whether the record for that parameter for the next higher level of jurisdiction contains a guideline and if so, characterizing that guideline as the applicable guideline;

if said record refers to a different record, characterizing the guideline contained in said different record as the applicable guideline.

16. A monitoring system as in claim 11 wherein said hierarchy includes jurisdictions at the municipal, state or provincial, and national levels.

17. A monitoring system as in claim 1 wherein said database includes information identifying monitoring requirements for a plurality of water quality parameters.

18. A monitoring system as in claim 17 wherein said monitoring requirements are a function of the sampling location and of the nature and size of the water system from which the sample is taken.

19. A monitoring system as in claim 17 wherein one of said input sources is a remote user submitting water quality data relating to a water quality parameter, and said database system provides to said remote user an identification of the monitoring requirements relating to said water quality parameter.

20. A monitoring system as in claim 19 wherein said database system provides a report of monitoring requirements to said remote user based on said analysis.

21. A monitoring system as in claim 20 wherein said report is also a function of historical information regarding water quality data provided by said remote user.

22. A monitoring system as in claim 21 wherein said historical information includes the frequency of water quality data provided in relation to a sampling location.

23. A monitoring system as in claim 22 wherein said historical information includes the frequency of water quality data provided by said remote user.

24. A monitoring system as in claim 17 wherein said database system provides recommendations regarding monitoring requirements based on said analysis.

25. A monitoring system as in claim 24 wherein said database system provides recommendations regarding monitoring requirements based on historical information relating to water quality data received from an input source.

26. A monitoring system as in claim 2 wherein said database system includes a web interface enabling remote users to input and access water quality data in said database system.

27. A system as in claim 22 wherein said database maintains information regarding the types of data preferred by particular remote users.

28. A monitoring system as in claim 2 wherein said database system receives and analyzes water quality data from a water facility operator, and said database

system provides recommendations to said facility operator to improve the quality of the water at said facility.

29. A monitoring system as in claim 19 wherein said recommendations include recommendations as to one or more of maintenance scheduling, sampling techniques and sampling frequency.

30. A monitoring system as in claim 1 wherein said database system displays results of said analysis in graphical and textual form.

31. A monitoring system as in claim 30 wherein said results include a comparison of measurement data in relation to a water quality parameter with guidelines for said water quality parameter.

32. A monitoring system as in claim 1 wherein, in response to a user enquiry regarding applicable water quality guidelines or the submission of water quality measurement data for a water quality parameter, said user interface displays a page of information comprising both the current guideline and any anticipated future guideline.

33. A monitoring system as in claim 1 wherein, in response to a user enquiry regarding applicable water quality guidelines or the submission of water quality measurement data for a water quality parameter, said user interface displays a page of information comprising a statement of the rationale for the guideline and a description of the element, compound, or physical or chemical effect to which the water quality parameter relates.

34. A monitoring system as in claim 32 or 33 wherein said page further comprises current and anticipated future monitoring requirements.

35. A monitoring system as in claim 32 wherein said page further comprises a statement of the rationale for the guideline, a description of the element, compound, or physical or chemical effect to which the water quality parameter relates, current monitoring requirements and anticipated future monitoring requirements.

36. A monitoring system as in claim 1 wherein said input sources include a data provider, and wherein said data provider can associate with measurement data a level of accessibility, and said database system uses said level of accessibility to selectively allow or disallow access to said measurement data by others.

37. A monitoring system as in claim 36 wherein said level of accessibility is a function of whether the user seeking access has specified the same level of accessibility for access to others by that user's measurement data.

38. A monitoring system as in claim 1 wherein said database system performs analysis of water distribution networks based on water quality data received from a plurality of input sources.

39. A monitoring system as in claim 38 wherein said analysis of water distribution networks includes the tracking of real-time conditions of water flow, pressure or level at points in the water distribution network.

40. A monitoring system as in claim 38 wherein said analysis of water distribution networks includes predicting the effect of changes effected at points within the water distribution network.

41. A monitoring system as in claim 1 further comprising server application software operative to control said user interface.

42. A monitoring system as in claim 41 wherein said server application software enables user-defined active server pages.

43. A monitoring system as in claim 41 wherein said database system includes a user database containing information relating to users of the system.

44. A monitoring system as in claim 43 wherein said user database stores water quality data supplied by said user.

45. A monitoring system as in claim 43 wherein said server application software enables user-defined active server pages and said user database comprises user preferences relating to the information to be displayed on said user-defined active server pages.

46. A monitoring system as in claim 45 wherein said information to be displayed comprises the water quality parameters said user is interested in.

47. A monitoring system as in claim 1 or 19 wherein said database system includes a knowledge database containing stored procedures and information regarding water quality management practices and said database system uses

said knowledge database to formulate recommendations to a water facility operator in relation to water quality management practices.

48. A monitoring system as in claim 10 wherein said database system further includes a user database containing information relating to users of the system, and a knowledge database containing stored procedures and information regarding water quality management practices.

49. A monitoring system as in claim 48 wherein said user database stores water quality data supplier by a user.

50. A monitoring system as in claim 10 wherein said database system notifies subscribed users of changes in governmental and regulatory guidelines for water quality.

51. A monitoring system as in claim 1 wherein said user interface includes the display of a pre-formatted data input interface.

52. A monitoring system as in claim 51 wherein said database system validates the water quality data input by a user into said data input interface.

53. A monitoring system as in claim 1 comprising bar codes associated with water sampling sites and further comprising bar code readers used by a user to scan said bar codes and communicating the bar code particulars to said database system.

54. A monitoring system as in claim 53 wherein said user interface selects a data input interface for display to a remote user according to the bar code particulars.

55. A monitoring system as in claim 54 wherein said data input interface further includes information identifying a water sampling site.

56. A monitoring system as in claim 55 wherein said data input interface further includes information regarding the types of analyses required for a water sampling site.

57. A monitoring system as in claim 53 wherein said bar codes associated with water sampling sites are marked on physical apparatus located at said sites.

58. A monitoring system as in claim 54 wherein said bar code particulars are used to select a display comprising a map including a water sampling site.

59. A centralized database for collecting water quality data over the Internet from a variety of remote sources, maintaining database information for each of said remote sources, analyzing the water quality data, and disseminating the data and the analysis to users that access the database remotely through the Internet.

60. A water quality monitoring system, comprising:

a centralized database system for collecting and storing water quality data;

a plurality of remote input sources communicating water quality data to said server;

said input sources including test laboratories communicating test results through data exchange with said database system;

analysis means associated with said database system for analyzing said water quality data;

a user interface associated with said database system for presenting water quality data to remote users through a distributed wide area network.

61. A monitoring system as in claim 60 wherein said input sources further include on-site water samplers entering measurement data through a browser in communication with said database system.

62. A monitoring system as in claim 61 wherein said data exchange occurs automatically when test results have been compiled for a given water sample.

63. A monitoring system as in claim 62 wherein further comprising a database of data exchange software programs to facilitate said data exchange.

64. A monitoring system as in claim 63 wherein said database system contains information associating each of said test laboratories with one of said data exchange software programs.

65. A monitoring system as in claim 62 wherein said database system comprises information regarding the testing procedures applied by said test laboratories.

66. A monitoring system as in claim 60 wherein said test results are maintained in a pre-defined staging portion of said database system and access to said staging portion is restricted to authorized users for the purpose of annotating said test results prior to allowing access to said test results by others.

67. A method of monitoring water quality comprising the steps of:

collecting water quality measurement from a sampling site;

communicating said measurement data to a remote database over a wide area network, said database containing one or more of: historical water quality data for said sampling site, guidelines associated with a water quality parameter;

receiving from said remote database a display of comparative information regarding one of more of: historical water quality data for said sampling site, guidelines associated with a water quality parameter.

68. A method for a test laboratory to supply to a remote database water quality measurement data, comprising the steps of:

receiving a sample of water to be tested;

testing said sample to derive therefrom test results comprising water quality measurement data;

establishing communication over a wide area network with a database for collecting and disseminating information regarding water quality;

effecting data exchange of said test results with said database;

communicating with said database to view water quality test results

69. A monitoring system as in claim 6 wherein said remote user is one of said input sources.

70. A monitoring system as in claim 1 wherein said database system performs analysis of water distribution networks based on the tracking of real-time conditions of water flow, pressure or level at points in the water distribution network.

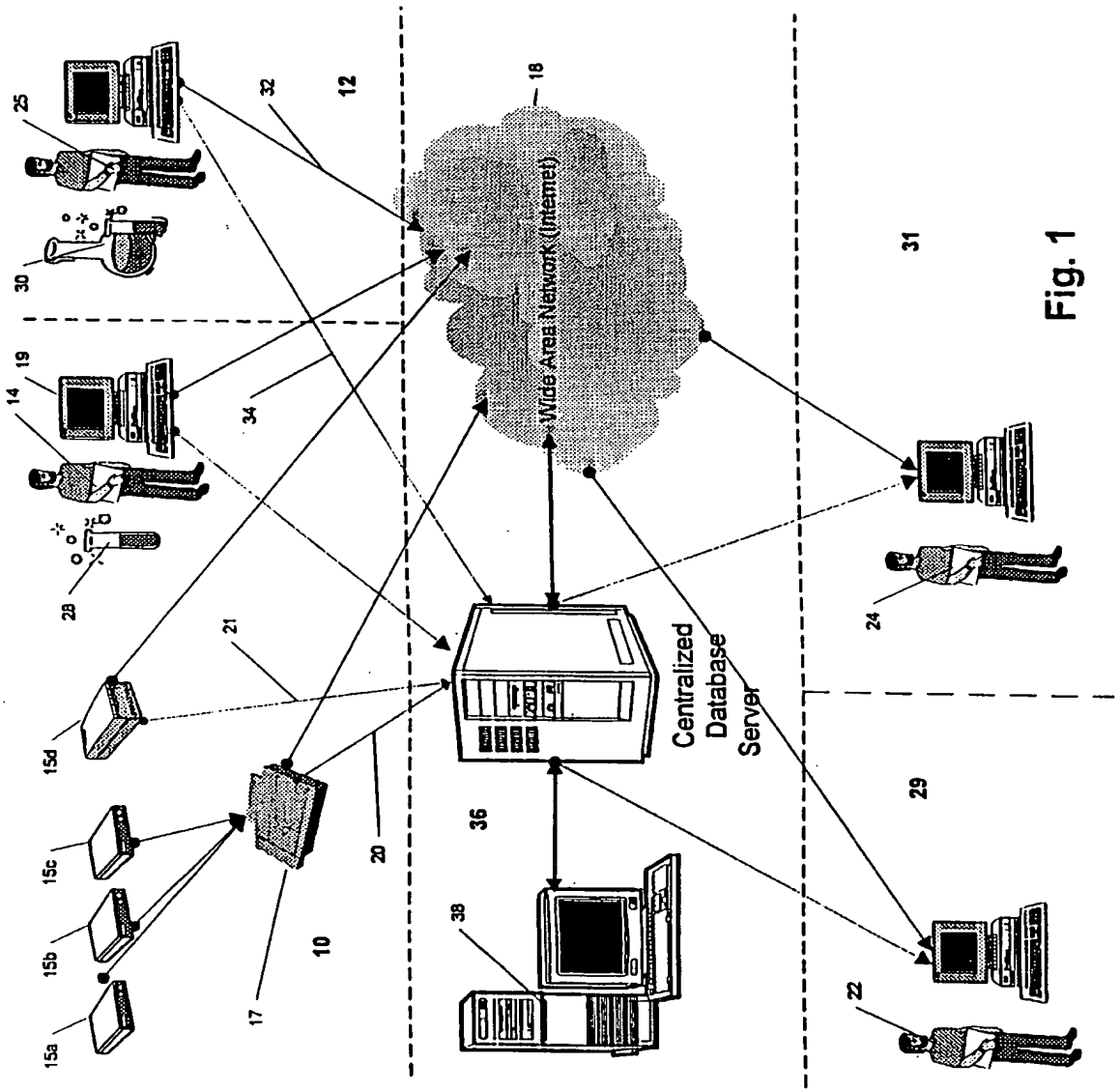

Fig. 1

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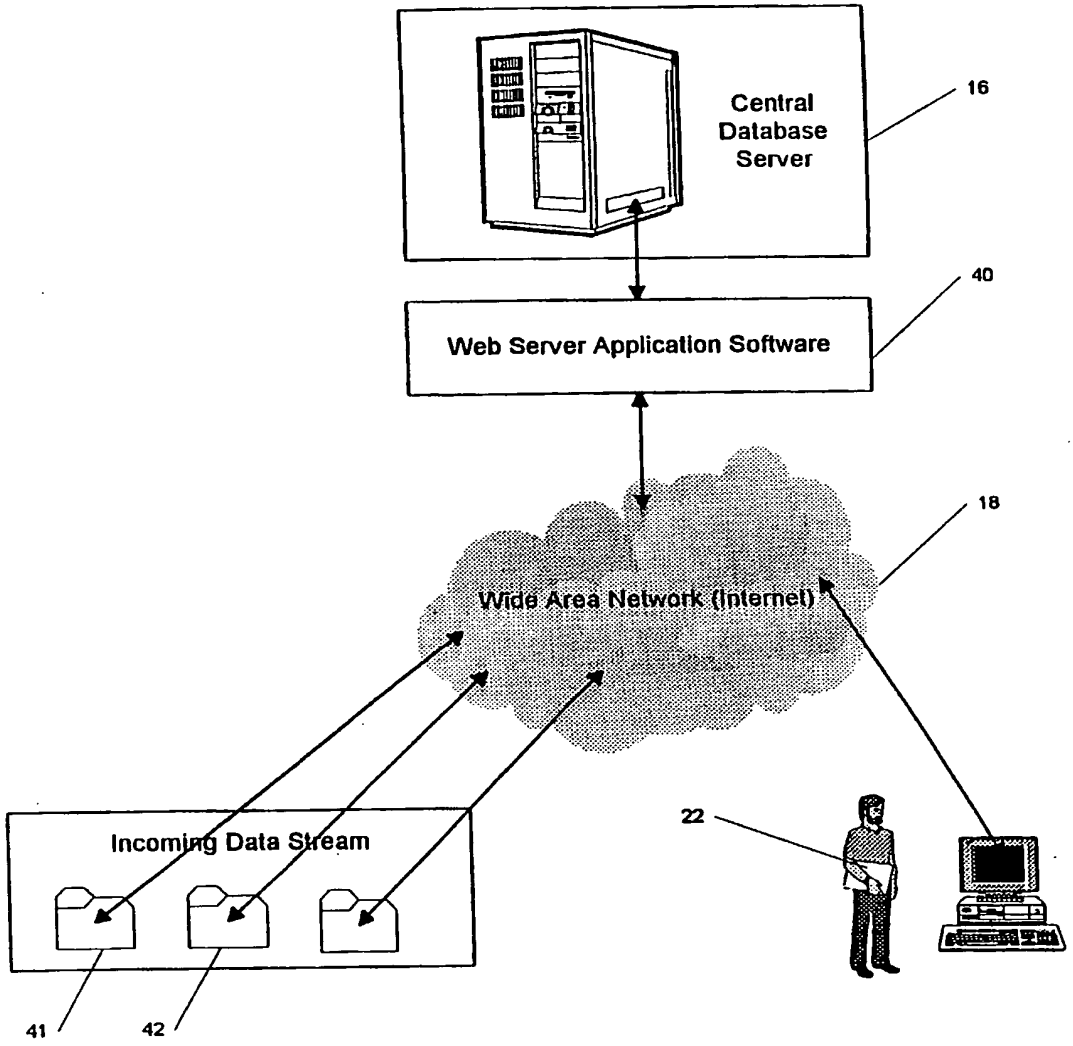

Fig. 2

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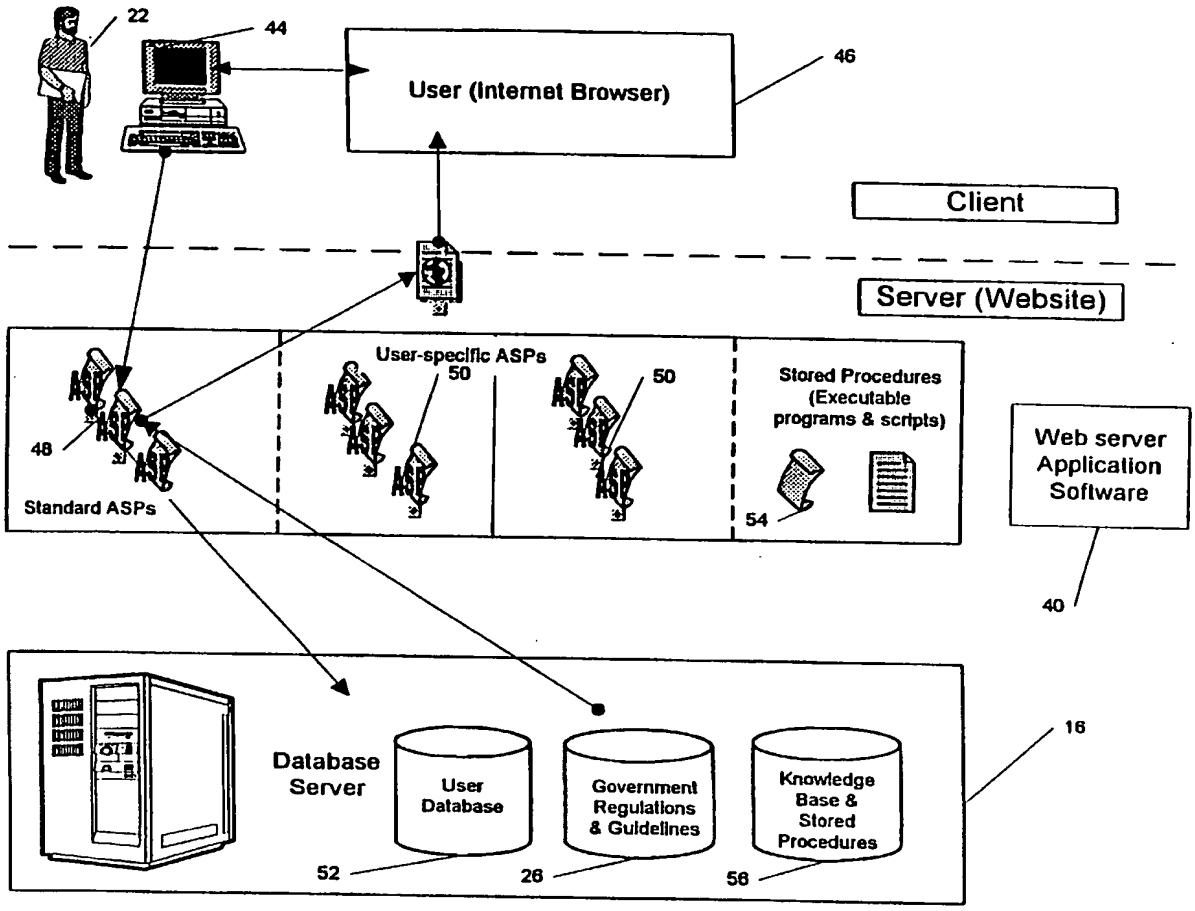

Fig. 3

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INTERNATIONAL SEARCH REPORT

Ir tional Application No
PCT/CA 01/00840

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N33/18 G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 021 664 A (GRANATO GREGORY E ET AL) 8 February 2000 (2000-02-08) the whole document ---	1-70
Y	KUWANO H ET AL: "NEW MULTIMEDIA COMMUNICATION SERVICES USING SENSING SYSTEMS. DEVELOPMENT OF WATER-QUALITY SENSING NETWORK SYSTEM" NTT REVIEW, TELECOMMUNICATIONS ASSOCIATION, TOKYO, JP, vol. 9, no. 1, 1997, pages 100-107, XP000643777 the whole document ---	1-70
A	US 6 023 223 A (BAXTER JR JOHN FRANCIS) 8 February 2000 (2000-02-08) cited in the application the whole document --- -/--	1-70

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 November 2001	28/11/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Joyce, D

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Ir ional Application No
PCT/CA 01/00840

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 002 863 A (SHEER DANIEL P ET AL) 14 December 1999 (1999-12-14) the whole document	1-70

1

INTERNATIONAL SEARCH REPORT

nformation on patent family members

International Application No
PCT/CA 01/00840

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6021664 A	08-02-2000	NONE	
US 6023223 A	08-02-2000	WO 0055823 A1	21-09-2000
US 6002863 A	14-12-1999	NONE	